An Introduction to the Dark Energy Survey

- A study of the dark energy using four independent and complementary techniques
  - Galaxy cluster surveys
  - Weak lensing
  - Galaxy angular power spectrum
  - SN Ia distances
- Two linked, multiband optical surveys
  - 5000 deg^2 *g'*, *r'*, *i'* and *z'*
  - Repeated observations of 40 deg^2
- Instrument and schedule
  - New 3 deg^2 camera on the Blanco 4m on Cerro Tololo
  - Construction: 2004-2008
  - Data Acquisition: 2008-2012

Blanco 4m on Cerro Tololo

Image credit: Roger Smith/NOAO/AURA/NSF

Joe Mohr (U Illinois) for the DES Collaboration SAGENAP - April 14, 2004
Fermilab, U Illinois, U Chicago, LBNL and NOAO/CTIO

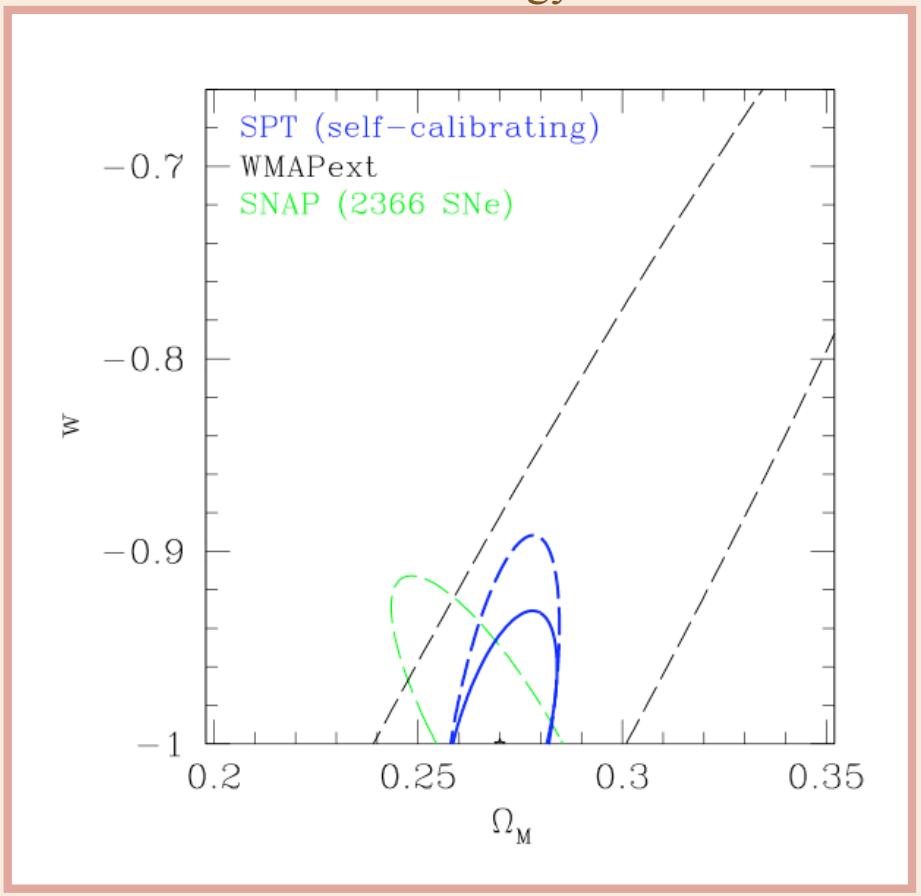
Cluster Survey Studies of the Dark Energy are Complementary and Competitive

- Cluster redshift distribution constrains volume surveyed and the growth rate of structure. Clustering of clusters provides independent cosmological constraints

- SZE cluster survey constraints on dark energy:
  - The cluster redshift distribution, the cluster power spectrum and 30% accurate mass measurements for 100 clusters between z of 0.3 and 1.2
  - Fiducial model is WMAP cosmology (σ_8=0.84, Ω_m=0.27 Ω_k=0); 29000 clusters in the 4000 deg^2 SPT survey.
  - The joint constraints on w and Ω_m:
    - *Curvature free to vary (dashed); fixed (solid)*
    - *Marginalized constant w 68% uncertainty is 0.046 (flat) or 0.071 (curvature varying)*

- Parameter degeneracies complementary to SNe/CMB, systematics differ

SPT+DES Dark Energy Forecasts



SPT: Majumdar & Mohr
SNAP: Perlmutter & Schmidt
WMAP: Spergel et al

Partnership with the 10m South Pole Telescope Team

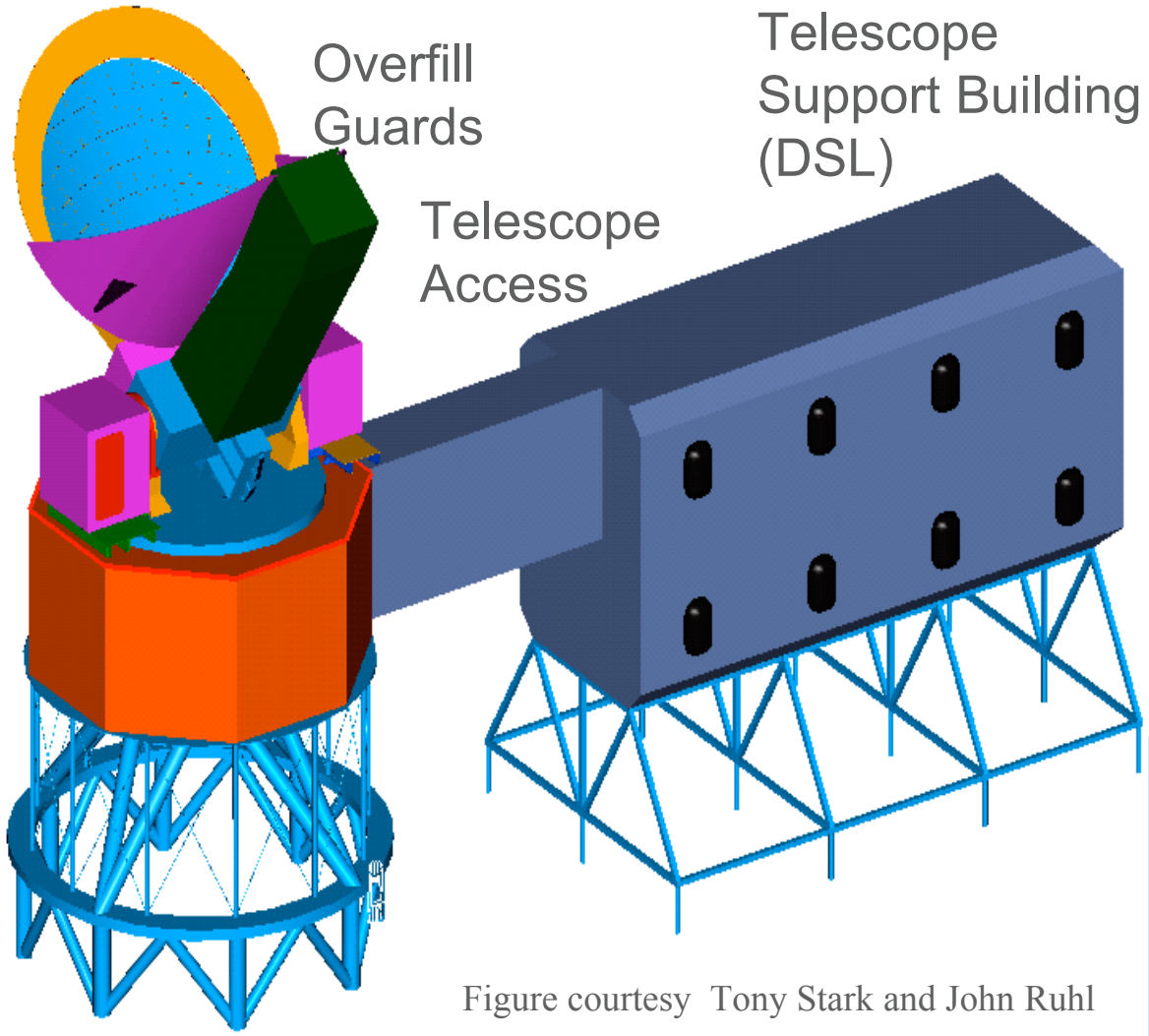


Figure courtesy Tony Stark and John Ruhl

PI John Carlstrom (U Chicago)

Collaborators at Chicago, CWRU, Berkeley, Illinois and Harvard-Smithsonian CfA

Goal: Study dark energy with cluster redshift distribution and cluster power spectrum out to z~1.5 and study CMB (polarization) on scales of 1 arcmin and above

Survey of 4000 deg^2 in three bands *begins Feb 2007*

Photometric Redshift Requirements

- The SPT 4000 deg^2 survey will yield roughly 29,000 clusters with WMAP+ cosmological parameters, the standard structure formation model and our current estimates of the survey cluster flux limit. So we will find roughly 7 clusters per deg^2. SPT SZE cluster survey will be south of declination -30^o.

- Photometric redshift estimates to z~1
  - Accuracy is acceptable (δz~0.02 with shallow SDSS data to z=0.6; Annis). Similar accuracy with deeper two-band photometry to z=1 (Yee & Gladders)
  - *g'*, *r'*, *i'* and *z'* photometry to 10 sigma depth of 24.6, 24.1, 24 and 23.6 would be sufficient for determining redshifts of those clusters to z~1.1 (>90% of our SPT sample)
  - Such a survey on the Blanco 4m with a 3deg^2 camera would take 600 nights
  - Some higher redshift systems will require near infrared followup

- Additionally, optical cluster finding and independent optical mass estimates are crucial
  - Estimating the completeness and contamination of our SZE sample
  - Overcoming contamination by dusty galaxies and radio galaxies

Dark Energy Survey Synergy

- The optical survey- driven by the need for cluster photometric redshifts- is well suited for (at least) two other sensitive probes of the dark energy:
  - A weak lensing study of projected matter fluctuations
  - Distance measurements using the galaxy power spectrum and its redshift evolution

- In addition, the long term nature of our survey and the very large camera are well suited for a time domain component focused on finding SNe
  - Repeated observations of 40 deg^2 at relatively low cost (10% of survey time)
  - Can improve survey efficiency during non-photometric conditions

DES Weak Lensing

- The main survey will deliver 10-20 galaxies/arcmin^2 (180-360 million total) appropriate for weak lensing studies
- Cosmic shear is produced by fluctuations in the matter density along the line of sight, and it is a promising technique for studies of the dark energy (i.e. Tyson, Kaiser, Bernstein, Jain, Hoekstra, Refregier and others)
- DES cosmic shear will be the first extracted on very large angular scales, where the modes are solidly in the linear regime
- LSST's larger solid angle survey, deeper photometry, better PSF (0.7" versus 0.9") and improved control of PSF variations will ultimately make it the best ground based weak lensing experiment

DES Weak Lensing Forecasts

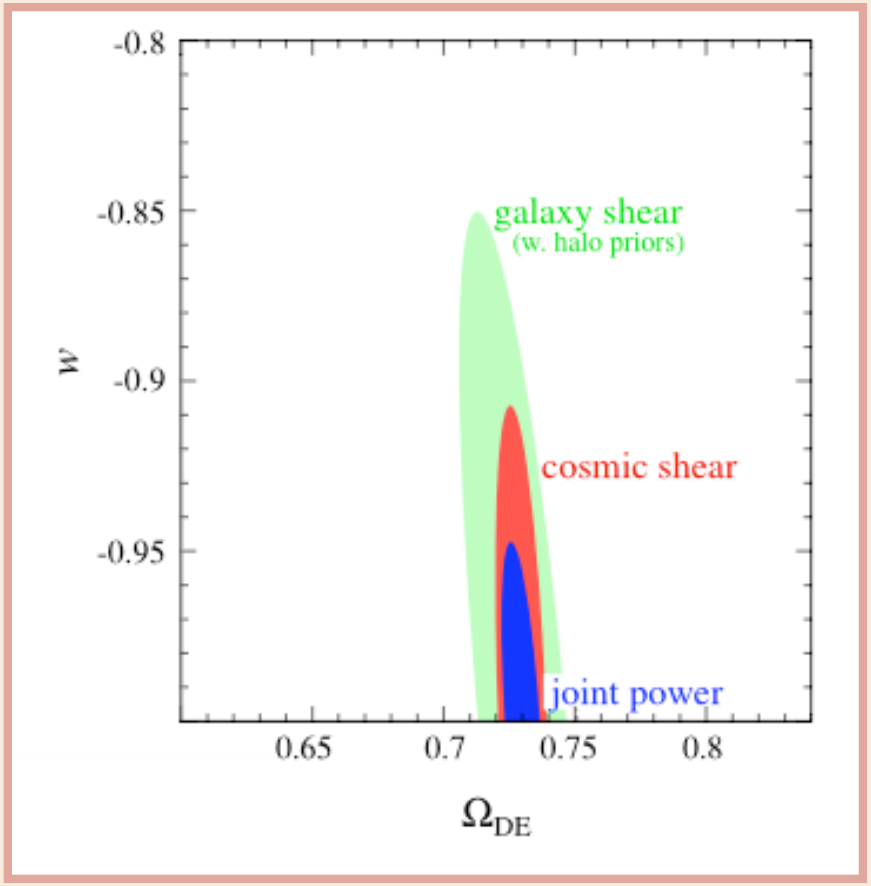


Figure from Hu, Frieman & Sheldon

Cosmic shear: shear-shear to *l*=3000

Galaxy-shear: shear-galaxy to *l*=3000 marginalizing over halo model parameters constrained by local galaxy angular power spectrum using only halos with $M>10^{13.5} M_o$

DES Galaxy Angular Power Spectrum

- DES main survey will yield photo-z's on approximately 300 million galaxies extending beyond a redshift z~1
- Photo-z uncertainties are too large to allow a full, 3D study of the galaxy clustering, but we can study the angular clustering within redshift shells to z~1
- Features in the angular power spectrum reflect "standard rods" that follow from simple physical arguments. These provide angular diameter distances as a function of redshift (i.e. Cooray et al 2001). The clustering amplitude is unimportant, and so the unknown galaxy bias is not a problem.
- Our current estimates are that we can place a 1σ constraint on constant **w** models of 0.1

SPT Cluster Angular Power Spectrum

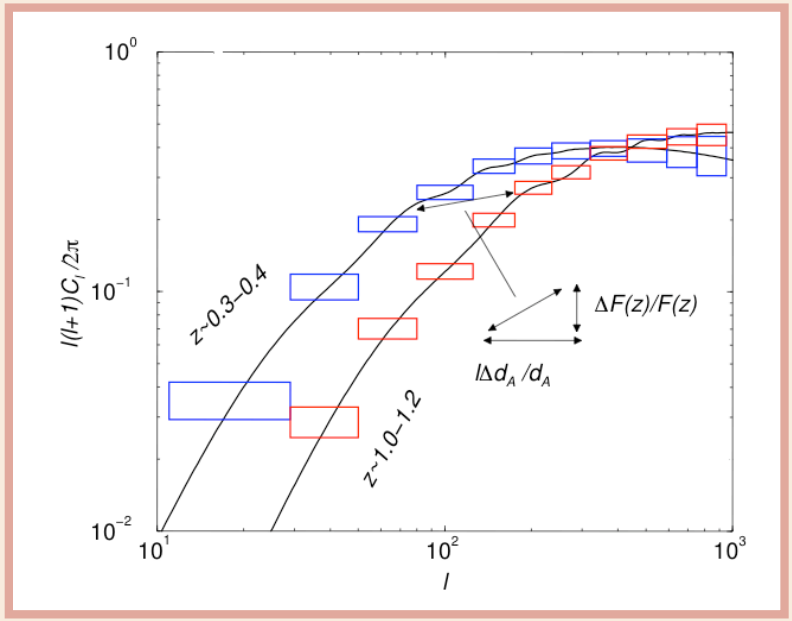


Figure from Cooray et al ApJ 2001

DES Supernova Ia Distances

- Repeated observations of 40 deg^2 to detect SNe and measure light curves
  - Expect 2000 SNe Ia distances at 0.3<z<0.8 over the life of the survey (assumes 10% of total survey time spent in this component)
- Expect roughly 25% of all SNe to lie within galaxies with spectroscopic redshifts
  - Co-locate DES fields with16 deg^2 with deep VLT spectroscopic surveys
  - Remainder followed up with coordinated spectroscopy, and others will be analyzed using photometric redshifts of galaxies in which they lie
  - Further development of photo-z SNe distance estimation will be important to success of LSST SNe component
  - (Overlap with VLT and DEEP2 fields important for photo-z calibration in main survey)
- Results in a powerful constraint on models with constant **w**

DES Supernova Ia + Cluster Survey Forecast

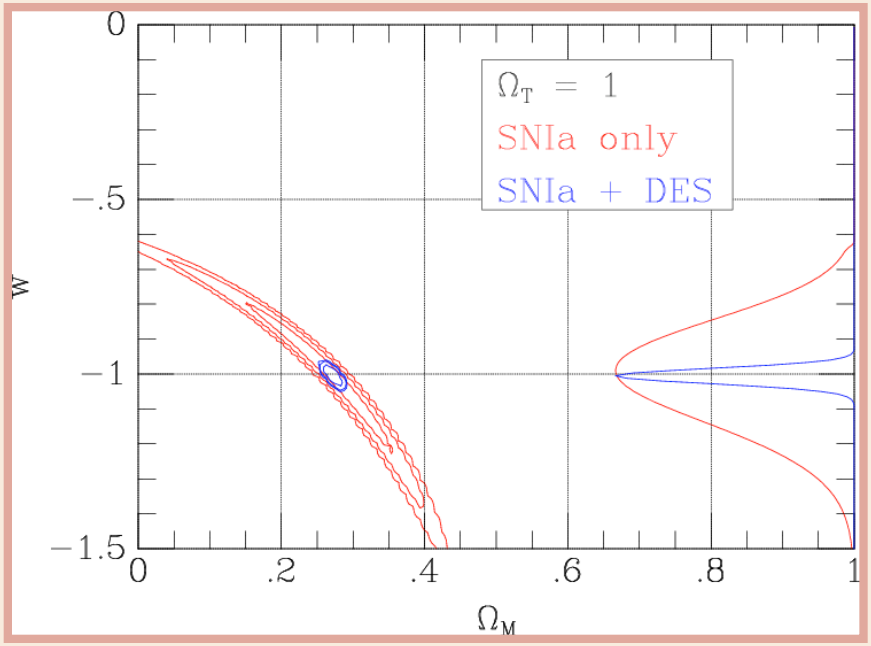


Figure from Smith, Maknaitus & Suntzeff

The Dark Energy Survey in Context

- Precise studies of the dark energy using four promising techniques:
  - cluster survey
  - weak lensing
  - galaxy angular power spectrum
  - SNe Ia distances
- Parameter degeneracies are complementary, systematics differ; these DES experiments will be the best in class at the time of the survey
- Near term experiment using an existing, national facility
  - Survey from 2008-2012 (5 years) with (partial) cluster survey and SNe results expected after the first year
  - Survey is ~10 times deeper than SDSS over comparable solid angle.
- An important precursor experiment
  - Next step in SNe beyond CFHT Legacy & Essence, and leading to SNAP & Destiny
  - Next step in cosmic shear beyond CFHT Legacy and leading to LSST
  - Data management challenges similar to (but simpler than) those faced by LSST. Each frame will be released to the public one year after acquisition.

NOAO/CTIO Partnership Opportunity

- NOAO/CTIO issued an announcement of opportunity last fall to build an instrument for the Blanco 4m in return for up to a third of the time over five years beginning in 2007 or 2008
  - This is driven by a long range interest in developing the Blanco and Mayall 4m telescopes as imaging machines to feed spectroscopic studies with the larger telescopes
  - Partnership proposals due July 15, reviewed by Blanco Instrumentation-partnership Review Panel (BIRP), final approval by AURA in Oct/Nov 2004
  - The Dark Energy Survey is the only active proposal
  - We are currently working in partnership with CTIO director Alistair Walker and others to refine the camera design and prepare the partnership proposal